Impact of salt and sugar reformulation on processing parameters for orange juice and tomatoes using ohmic heating

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Abstract

Purpose–

The purpose of this research is in twofold: first, it aims to investigate how salt and sugar reduction in foods due to the pressure from the emerging food regulations will affect the physico-electrical properties (PEPs) of orange juice and tomatoes during a selected PEP-dependent thermal processing. Second, the authors are keen to understand how variations in salt and sugar ingredients will affect the time-temperature processing requirements.

Design/methodology/approach–

PEPs of the samples (orange juice and tomatoes) were measured using the KD2 thermal analyser and RS conductivity meter. Both samples with varying salt and sugar levels were subjected to Ohmic Heating processing using a 10kW Ohmic Heater. Dehydration rates and processing times for pasteurisation were obtained.

Findings–

Electrical conductivity increases with added salt in tomato puree but decreases with added sugar in orange juice. Statistical evidence confirmed significant changes in heating rates and processing times of tomatoes and orange juice as their relevant salt and sugar levels change. Reduction in salt content in tomato puree led to increase in time and energy for the thermal processes. While reduction in added sugar in orange juice results led to reduction in processing time and energy requirement for the processing operation.

Research limitations–

The study is limited to small change in salt and sugar variations in order to reflect recommended limits. There were therefore no significant changes in thermal conductivity for the range investigated. Also this study is focused on two food products.

Practical implications–

Current pressure on the need to reduce salt and sugar in foods necessitates research to increase food processing industry insight into the process and product impacts of such recipe changes, with particular regard to processing efficiency and product safety and quality.

Originality/value–

This study represents an attempt to understand the impact of salt and sugar variations on properties and processing requirements of tomato puree and orange juice.

Keywords Ohmic heating, dehydration, pasteurisation, salt, sugar, food processing
Paper type Research paper

1 Introduction

The importance of developing new food products with reduced salt and sugar is growing due to the associated potential health benefits. There have been several calls for food reformulation toward reducing their salt and sugar contents (Reeve and Magnusson, 2015; Heredia-Blonval et al., 2014). Excessive salt intake has been proven to relate to high blood pressure, stroke and coronary heart disease; while excessive dietary sugar intake causes dental caries, overweight, heart disease and type-2 diabetes (NHS Choices, 2015). The £10 million Innovate UK call from October 2015 to March 2016 titled “Optimising food composition” was specifically focused on reducing levels of salt, sugar, saturated fat and/or total fat, and increasing levels of dietary fibre. Further accentuating the ongoing sector and policy pressure for food reformulation with respect to reducing salt and sugar content. Also some European Union legislations have focussed on food reformulation by redefining maximum allowable levels for some food components (Belc et al., 2019).

While attempts are being made to reduce salt and sugar content in food, the effect of this reduction on food thermal and electrical properties should also be investigated. This is because the operations of some of the existing and emerging food processing equipment are based on the thermo-physical and electrical properties of the foods being processed. One such emerging processing equipment considered in this study is Ohmic Heating System (OHS). It is important to note that these food properties are not only crucial in the accurate design of the processing equipment but also in the accurate prediction of temperature changes during the heat treatment operations which if miscalculated can seriously affect key factors of process efficiency and product safety / quality. For example, one food safety related issue caused by changing product compositions resulted in the largest outbreak of foodborne botulism in the UK with 27 patients affected (O’Mahony et al., 1990).

OHS use two or more electrodes to transfer heat energy directly into the entire mass of food materials rather than via a heat transfer medium. Direct transfer of heat to processed foods reduces problems associated with product fouling on the food contact surfaces of traditional heat exchangers. Also, direct transfer heat energy through electrical energy into the entire mass of food materials rather than via a heat transfer medium providing potential added benefit of efficiency in energy conversion. However, the system has not been used extensively in food processing at an industrial scale. While there is a lack of general awareness of the benefits of Ohmic heating among food manufacturers, other factors responsible for its limited use at an industrial scale include equipment cost and availability; equipment capacity; and regulatory approval. Because the products are heated directly rather than via a heating exchanger system. Absence of a heat exchange system other than the foods being processed in OHS implies that the thermo-physical and electrical properties of the foods being processed will greatly influence its performance.

Studies have been carried out to evaluate the influence of electrical conductivity on ohmic heating rate (Darvishi et al. 2012), the effect of the electric field frequency on food properties during ohmic heating (Cho et al., 2016; Mercali et al., 2014; Shynkaryk et al., 2010; Bansal and Chen, 2006; Kulshrestha and Sastry, 2006), the effect of varying electric field and salt concentration of the water surrounding the food being processed (Pedersen et al., 2016; Wongsa-Ngasri and Sastry, 2015; Wongsa-Ngasri and Sastry, 2016). Other studies have also demonstrated the benefits of using OHS for thermal processing, especially in the preservation of heat-sensitive components such as volatile organic compounds and thus resulting in the production of foods with enhanced organoleptic properties (Achir et al., 2016; Roux et al., 2016). However, there is a paucity of research related to how variations in salt and sugar contents in food and drink will affect the thermal and electrical properties, and consequently the heating rates when processed by OHS. As the pressure to reduce added salt and sugar in food and drink grows, the importance of understanding how implementation of these reductions will affect thermal and electrical properties of food and drink, and their time-temperature processing requirements using OHS cannot be overemphasised.

2 Materials and Methods

2.1 Sample Preparation

Orange *(Citrus sinensis)* juice and fresh cherry tomatoes *(Lycopersicon esculentum)* (all drawn from the same production batch) were used for the experiments. The tomato samples were blended and thoroughly mixed to obtain fresh tomato puree. Puree consistency at 17ºC was 3.5 on the Bostwick scale (with the trough running for 20 seconds) when measured on a 24cm Bostwick Consistometer (Camlab, UK) and puree density was confirmed to be 660 kg/m^3.

2.2 Methods-Thermal and Electrical Conductivities

The World Health Organisation (WHO) recommends 2g per day sodium consumption for adults which is equivalent to 5g salt per day (WHO, 2012). For sugar intake, the WHO recommends 25g of sugar per day for an adult with a normal body mass index (Jaslow, 2014). With regard to the current % of an adult's reference intake, foods with "low" salt content will be containing 0.3g or less salt per 100g of food and foods with high salt content will be containing 1.5g or more salt per 100g of food. These figures are similar to the European Commission for Food Nutrition Claims. For example in the United Kingdom National Health Scheme Choice, foods containing 0.3g or less salt per 100g of food are classified as low salt foods while high salt foods contain 1.5g or more salt per 100g of food; and for sugar, foods containing 5g or less total sugar per 100 g are classified as low sugar foods, while foods containing 22.5g or more total sugar per 100g of food are classified as high sugar foods (the UK NHS Choice, 2015). Using these guidelines, the effect of added salt on thermal and electrical conductivities of fresh tomato puree was investigated from 0 to 1.4 grams of salt to 100 grams of tomato puree, while the effect of added sugar on thermal and electrical conductivities of fruit juice was investigated from 0 to 25 grams of sugar to 100 grams of juice.

2.3 Equipment and procedure- Thermal and Electrical Conductivities

The electrical conductivities were measured using the RS Pro 180-7127 conductivity meter (RS Components Ltd, Corby, UK). The thermal properties of the food samples were analysed and measured by KD2 Pro Thermal Properties Analyzer (Decagon Devices, USA). The measurement method for the thermal properties was based on the ASTM and IEEE thermal conductivity measurement standards (IEEE442 and ASTM 5334). Three measurements were taken for the electrical and thermal conductivities.

2.4 Methods - Ohmic Heating Processing

The Ohmic heating cell of dimension 30.0 x 9.0 x 9.6 cm was used for tomato puree processing, while 18.0 x 9.0 x 9.6 cm cell was used for juice processing, as shown in Figure 1. The cells were filled with fresh sample for each experimental run (Tomato puree of mass 0.66kg and density of 660kg/m^3, and orange juice of mass 0.50kg and density of 1035kg/m^3). Orange juice was subjected to pasteurisation heat treatment with target temperature of 75^{o}C while fresh tomato puree made from cherry tomatoes was subjected to dehydration, heated from room temperature to 100^{o}C for 900 seconds. TKTPs indicates the positions of the Type K Thermocouple Position.

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Figure 1: The ohmic heating cell dimension for tomato puree* and juice** processing

A 10kW Ohmic Heater (C-Tech Innovation, Chester, UK) was used for both heat treatments. Dehydration heat treatment was carried out using manual power setting at 50% while pasteurisation heat treatment was carried out using the heater auto power setting. The effect of added salt on temperature development during dehydration treatment by Ohmic heating for the fresh tomato puree was investigated from 0 to 15 grams of added salt to 660 grams of fresh tomato puree. This takes into consideration the current recommendations for low to high salt content in foods, as shown in Table 1 summarising the nutritional information of the samples. The effect of added sugar on temperature development during pasteurisation treatment by the Ohmic heater for the juice was investigated from 0 to 125 grams of sugar to 500 grams of juice. This also takes into consideration current recommendations for low to high sugar content in foods, as shown in Table 1, which summarises the nutritional information of the experimental samples.

Insert

Table 1: Nutritional information of experimental samples

Sample temperatures were recorded at four different positions (as shown in Figure 1) in the Ohmic cell during the thermal treatments using PICO TC-08 data logger (PICO Technology, Eaton Socon, St Neots, UK). Figure 2 shows the set-up for the ohmic heating system.

Insert

Figure 2: Ohmic Heating Experimental Set-up

2.5 Statistical Analysis

Repeated measured (one-way ANOVA analyses) were performed using IBM Statistical Package for the Social Sciences (SPSS) software (Version 22, IBM Corp). This analysis is useful for determining a significant difference across 3 or more sets of data. Comparative analyses of temperature developments for each of samples involve independent temperature variables measured at four different positions for each of the sample in the ohmic cell. The hypotheses are as follows:

> *H0: No difference in temperature developments across various positions in the cell during ohmic heating processing, i.e. temperature development is constant throughout the chamber.*
>
> *H1: Significant difference in temperature development exists across various positions in the ohmic cell, i.e. temperature development is not the same throughout the chamber.*

Comparative analyses of temperature developments for food products with varying salt or sugar content involve the independent variables of average temperature development in the ohmic cell. The hypotheses are as follows:

> *H0: Added salt/sugar has no effect on ohmic heating processing of food.*
>
> *H1: Added salt/sugar has significant effect on ohmic heating processing of food.*

3 Results and Analysis

3.1 Thermal and Electrical Conductivities

Effect of Salt and Sugar on Thermal Conductivities of Samples

Over the range of added salt investigated, the change in thermal conductivity of the fresh tomato puree did not change significantly with increase in the amount of added salt. As shown in Figure 3, the measure of goodness-of-fit of linear regression is 0.2160 and this implies only 21.60% of the variability in thermal conductivity can be explained by the variability in added salt to 100 grams of tomato puree. In addition, the slope of the trend line tends to zero and this implies that no significant relationship exists between the thermal conductivity and the amount of added salt to tomato puree over the range investigated. On the other hand, thermal conductivity of the juice slightly decreases from 0.55 to 0.48 W/(m.K) as the amount of added sugar increases from 0 to 12.5 grams (Figure 3). This property remains constant at 0.48 W/ (m.K) as added sugar increases from 12.5 to 25 grams. The negative slope (-0.0029) of the trend line confirms a decrease in thermal conductivity as the amount of added sugar increases. However, the value of the slope which tends to zero implies that thermal conductivity of the juice is not significantly affected by the amount of added sugar over the range investigated.

Insert

Figure 3: Effect of Salt and Sugar on Thermal Conductivity of Samples

Effect of Salt and Sugar on Electrical Conductivities of Samples

Electrical conductivity of the puree increased as the amount of added salt increased (Figure 4). Figure 4 shows further that the measure of goodness-of-fit of linear regression is 0.9931 and this implies 99.31% of the variability in electrical conductivity can be explained by the variability in added salt to 100 grams of tomato puree. In addition, the slope of the trend line is 9.3548; this implies that positive relationship exists between the electrical conductivity and the amount of added salt to tomato puree over the range investigated. This confirms that electrical conductivity increases as the amount of added salt increases and this agrees with the findings from Darvishi et al. (2012). Figure 4 also summarises the effect of added sugar on electrical conductivity of fruit juice. As shown, electrical conductivity of the sample decreases as the amount of added sugar increases. The slope -0.0733 of the trend line implies that negative relationship exists between the electrical conductivity and the amount of added sugar to fruit juice over the range investigated; hence electrical conductivity decreases as the amount of added sugar increases.

Insert

Figure 4: Effect of Salt and Sugar on Electrical Conductivity of Samples

3.2 Temperature developments in ohmic heating cell at varying salt and sugar levels

As shown in Table 2, findings from the one-way repeated measured ANOVA revealed a significant difference in temperature developments across the four positions of temperature measurement in the ohmic cell for each of the food samples at all salt and sugar levels investigated ($p < 0.001$, at 5% significant level).

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Table 2: Comparative analyses of the temperature developments during Ohmic heating over varying salt* and sugar levels**

3.3 Tomato Puree Dehydration

Figure 5 confirmed the findings from the statistical analyses as the figure shows while it took 300 seconds for puree sample with 15g of added salt to reach 100^{o}C, the same amount of puree with 2.5g of added salt required 810 seconds to reach the target temperature of 100^{o}C. This implies that as the amount of added salt increases, heating time required to reach 100^{o}C decreases. In addition, the amount of water removed during 900-second ohmic heating processing varies with the amount of added salt. Figure 6 shows that the amount of water removed and the heating rate of tomato puree depends on the amount of added salt. As the amount of added salt increases, the amount of water removed from the puree increases, as shown in Figure 6. Such effects have the potential for positive impact on the operating efficiency and control of related food processing operations.

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Figure 5: Temperature-Heating Time Curves for 660g Tomato Puree Dehydrated at different salt levels

Insert

Figure 6: Dehydrated water (g) during ohmic heating processing of 660g tomato puree at different salt levels

3.4 Fruit Juice Pasteurisation

Findings show pasteurisation time varies with the amount of sugar added to the fruit juice. When compared with the effect of added salt, it is interesting to note that the amount of added sugar has an opposite effect on the heating rate. Added sugar decelerates the heating process. As shown in Figure 7, juice with no added sugar reached the target pasteurisation temperature of 75°C in 285 seconds while juice with 125g of added sugar required 510 seconds to reach the same temperature. The time required to reach the target temperature of 75°C increases steadily as the amount of added sugar increases. These findings agreed with the initial preliminary findings on the effect of salt and sugar on the electrical conductivity. The findings show the significance of electrical conductivity of foods in ohmic heating processes. The required processing time to achieve target temperature decreases as electrical conductivity of foods increases.

Insert

Figure 7: Temperature-ohmic heating time curves for 500g juice pasteurisation at different sugar levels

4 Conclusions

As shown in this study, sugar and salt have opposite effects on the electrical conductivity. While the electrical conductivity increased with added salt, the property decreased with added sugar. Similarly, this study has also demonstrated that added salt and sugar responds differently to ohmic heat processing. With respect to the thermal conductivity of the foods tested, insignificant changes were observed for the range investigated for both added sugar and salt. This confirms findings from the literature that effectiveness of ohmic processing depends on the electrical conductivity of the foods being processed, and that thermal conductivity of food does not affect the effectiveness of ohmic heating (Darvishi et al. 2012; Cho et al., 2016).

Statistical evidence confirmed significant changes in heating rates and processing times of orange juice as the amount of added sugar changes. Findings also confirmed significant changes in processing times, dehydration and heating rates of tomato puree as the amount of added salt changes. While added salt reduced the processing time exhibiting rapid heating and dehydration rates, added sugar showed the opposite effect. As food salt content decreased, more time and energy was required for the thermal process using the ohmic heating methodology. Reduction in added sugar resulted in reduction in the processing time and this implies a reduction in energy requirement for the processing operation.

Findings from this study show that the rate of heating by the ohmic heater; the dehydration rate; and the time to reach the target temperature, are all affected by the amount of added salt and sugar in the investigated samples. As the amount of added salt in the food sample increases, the heating rate increases, and consequently, the time required to reach the target temperature decreases. This implies that energy required for ohmic heat processing of foods and its associated costs decrease as their salt content increases. On the other hand, as the amount of added sugar in food sample increases, heating rate decreases, and consequently, the time required to reach the target temperature increases. This implies that energy required for heat processing of foods and its associated costs will increase as their sugar content increases. This finding is significant because while ohmic heat processing of food supports the call for reduction in sugar in food; reduction in food salt level adversely affects the effectiveness and processing efficiency of ohmic heating technology. This study therefore confirms the significance of hurdle technology (Leistner, 2000) towards ensuring a right and intelligent combination of hurdles is applied during any food processing operations. While the current regulatory and public health awareness pressures on the need to reduce the intake of salt and sugar are attracting the needed attention, their impact on different food processing operations and conditions require thorough research. It is important to note that this study is limited to two food samples. Additional work is required to understand how salt and sugar variations will affect a wide variety of relevant foods when using ohmic heating technology.

References

Achir, N., Dhuique-Mayer, C., Hadjal, T., Madani, K., Pain, J. & Dornier, M. (2016), "Pasteurization of citrus juices with ohmic heating to preserve the carotenoid profile", *Innovative Food Science & Emerging Technologies,* vol. 33, pp. 397-404.

Bansal, B. & Chen, X.D. (2006), "Effect of Temperature and Power Frequency on Milk Fouling in an ohmic Heater", *Food and Bioproducts Processing,* vol. 84, no. 4, pp. 286-291.

Belc, N., Smeu, I., Macri, A., Vallauri, D., Flynn, K. (2019), “Reformulating foods to meet current scientific knowledge about salt, sugar and fats”, *Trends in Food Science & Technology*, vol. 84, pp. 25-28.

Cho, W., Yi, J.Y. & Chung, M. (2016), "Pasteurization of fermented red pepper paste by ohmic heating", *Innovative Food Science & Emerging Technologies,* vol. 34, pp. 180-186.

Darvishi, H., Hosainpour, A. & Nargesi, F. (2012), "Ohmic Heating Behaviour and Electrical Conductivity of Tomato Paste", *J Nutr Food Sci,* vol. 2, no. 9, pp. 1-5.

Heredia-Blonval, K., Blanco-Metzler, A., Montero-Campos, M. & Dunford, E.K. (2014), "The salt content of products from popular fast-food chains in Costa Rica", *Appetite,* vol. 83, pp. 173-177.

Jaslow, R. (2014), “World Health Organisation lowers sugar intake recommendations”, CBS News March 5 2014, CBS Interactive Inc., available at: http://www.cbsnews.com/news/world-health-organization-lowers-sugar-intake-recommendations/ (assessed 21 July 2016).

Kulshrestha, S.A. & Sastry, S.K. (2006), "Low-frequency dielectric changes in cellular food material from ohmic heating: Effect of end point temperature", *Innovative Food Science and Emerging Technologies,* vol. 7, no. 4, pp. 257-262.

Leistner, L. (2000), “Basic aspects of food preservation by hurdle technology”, *International Journal of Food Microbiology*, vol. 55, pp. 181-186

Mercali, G.D., Schwartz, S., Marczak, L.D.F., Tessaro, I.C. & Sastry, S. (2014), "Ascorbic acid degradation and color changes in acerola pulp during ohmic heating: Effect of electric field frequency", *Journal of Food Engineering,* vol. 123, pp. 1-7.

NHS Choices (2015), “*Fat: the facts* [Homepage of UK National Health Scheme]”, available at: http://www.nhs.uk/Livewell/Goodfood/Pages/Fat.aspx (assessed 25 November 2015).

O'Mahony, M., Mitchell, E., Gilbert, R.J., Hutchinson, D.N., Begg, N.T., Rodhouse, J.C. & Morris, J.E. (1990), "An outbreak of foodborne botulism associated with contaminated hazelnut yoghurt.", - Epidemiology and Infection, vol. 104, no. 3, pp. 389-395.

Pedersen, S.J., Feyissa, A.H., Brøkner Kavli, S.T. & Frosch, S. (2016), "An investigation on the application of ohmic heating of cold water shrimp and brine mixtures", *Journal of Food Engineering,* vol. 179, pp. 28-35.

Reeve, B. & Magnusson, R. (2015), "Food reformulation and the (neo)-liberal state: new strategies for strengthening voluntary salt reduction programs in the UK and USA", *Public health,* vol. 129, no. 4, pp. 351-363.

Roux, S., Courel, M., Birlouez-Aragon, I., Municino, F., Massa, M. & Pain, J. (2016), "Comparative thermal impact of two UHT technologies, continuous ohmic heating and direct steam injection, on the nutritional properties of liquid infant formula", *Journal of Food Engineering,* vol. 179, pp. 36-43.

Shynkaryk, M.V., Ji, T., Alvarez, V.B. & Sastry, S.K. (2010), "Ohmic Heating of Peaches in the Wide Range of Frequencies (50 Hz to 1 MHz)", *Journal of Food Science,* vol. 75, no. 7, pp. 493-500.

WHO, (2012), “Guideline: Sodium intake for adults and children”, Geneva, World Health Organisation

Wongsa-Ngasri, P. & Sastry, S.K. (2016), "Tomato peeling by ohmic heating with lye-salt combinations: Effects of operational parameters on peeling time and skin diffusivity", *Journal of Food Engineering,* vol. 186, pp. 10-16.

Wongsa-Ngasri, P. & Sastry, S.K. (2015), "Effect of ohmic heating on tomato peeling", *LWT - Food Science and Technology,* vol. 61, no. 2, pp. 269-274.

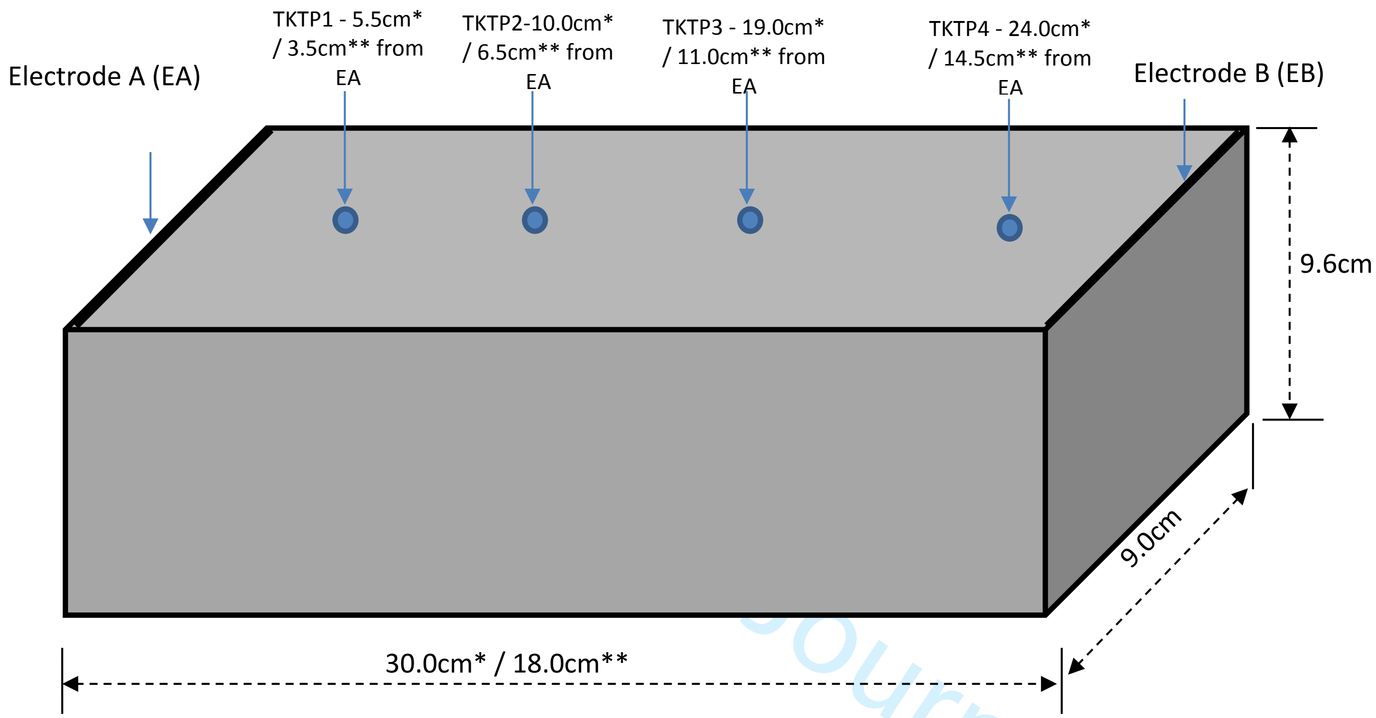

Figure 1: The ohmic heating cell dimension for tomato puree* and juice** processing

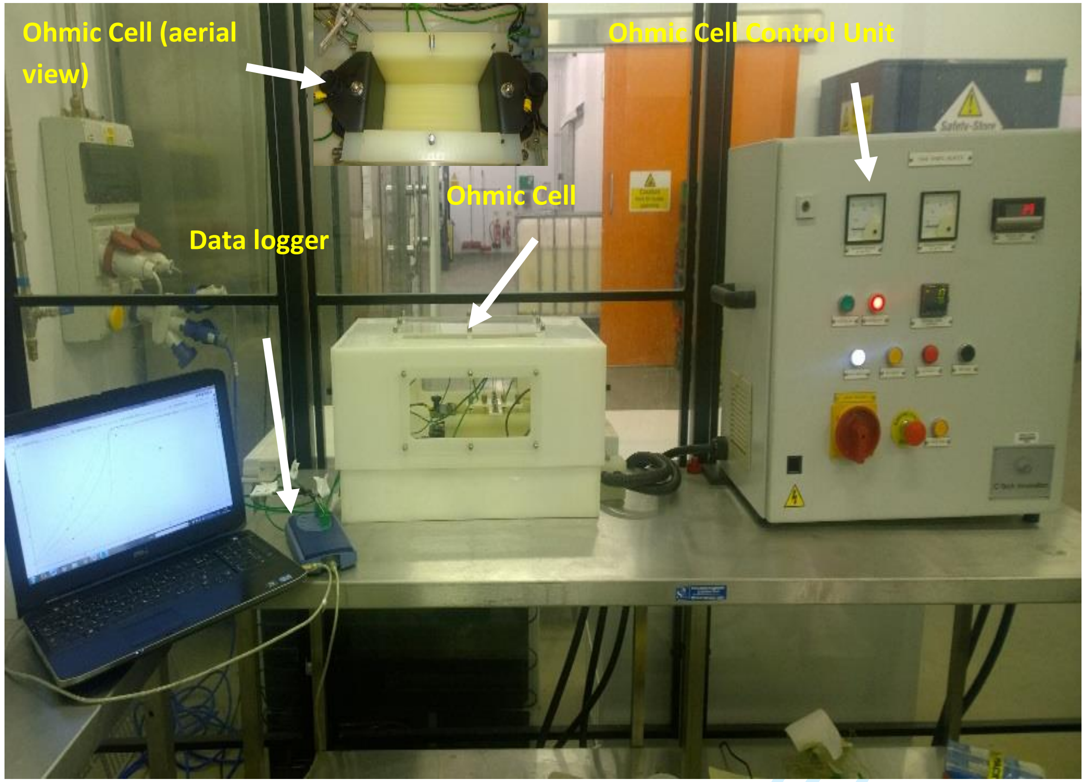

Figure 2: Ohmic Heating Experimental Set-up

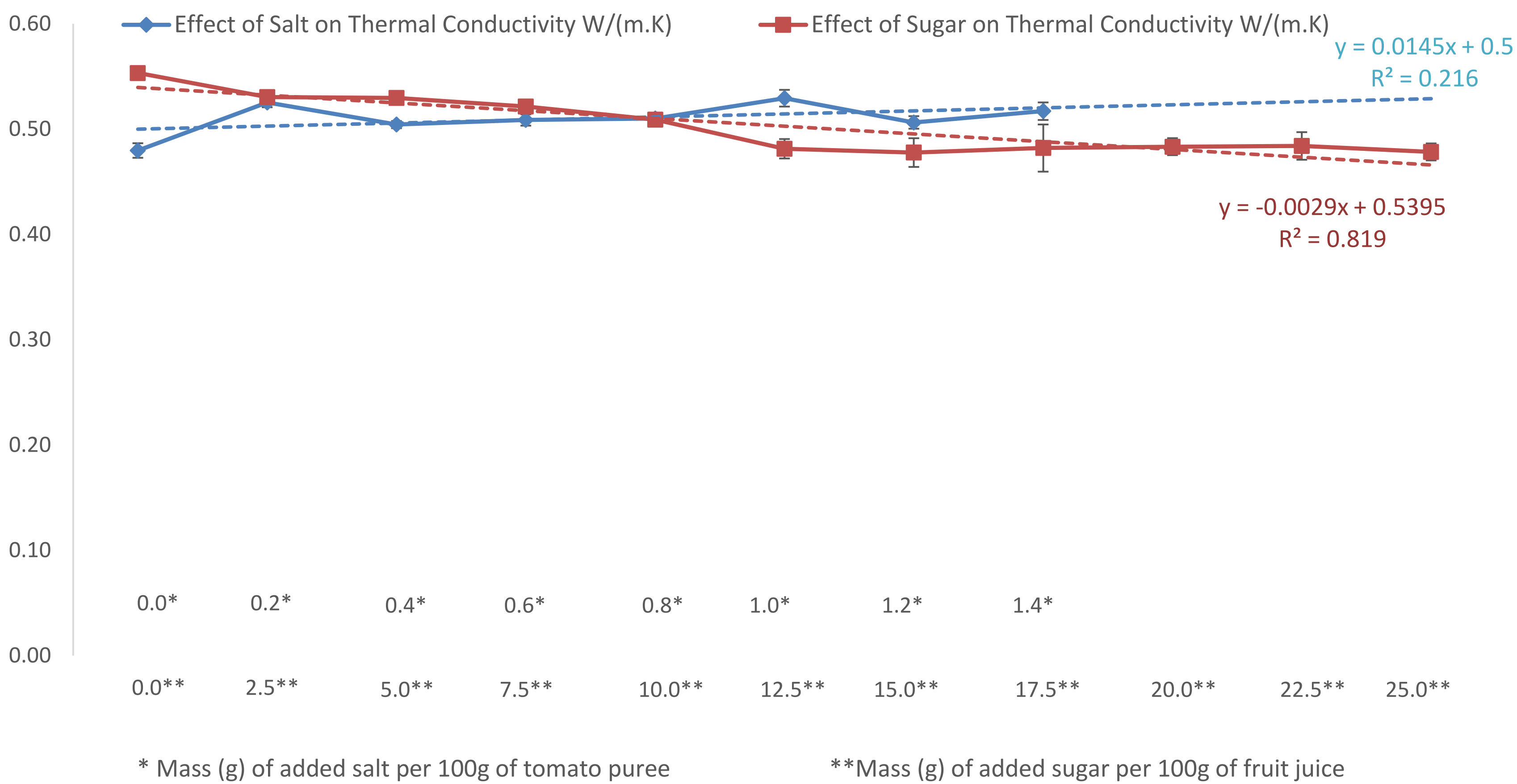

Figure 3: Effect of Salt and Sugar on Thermal Conductivity of Samples

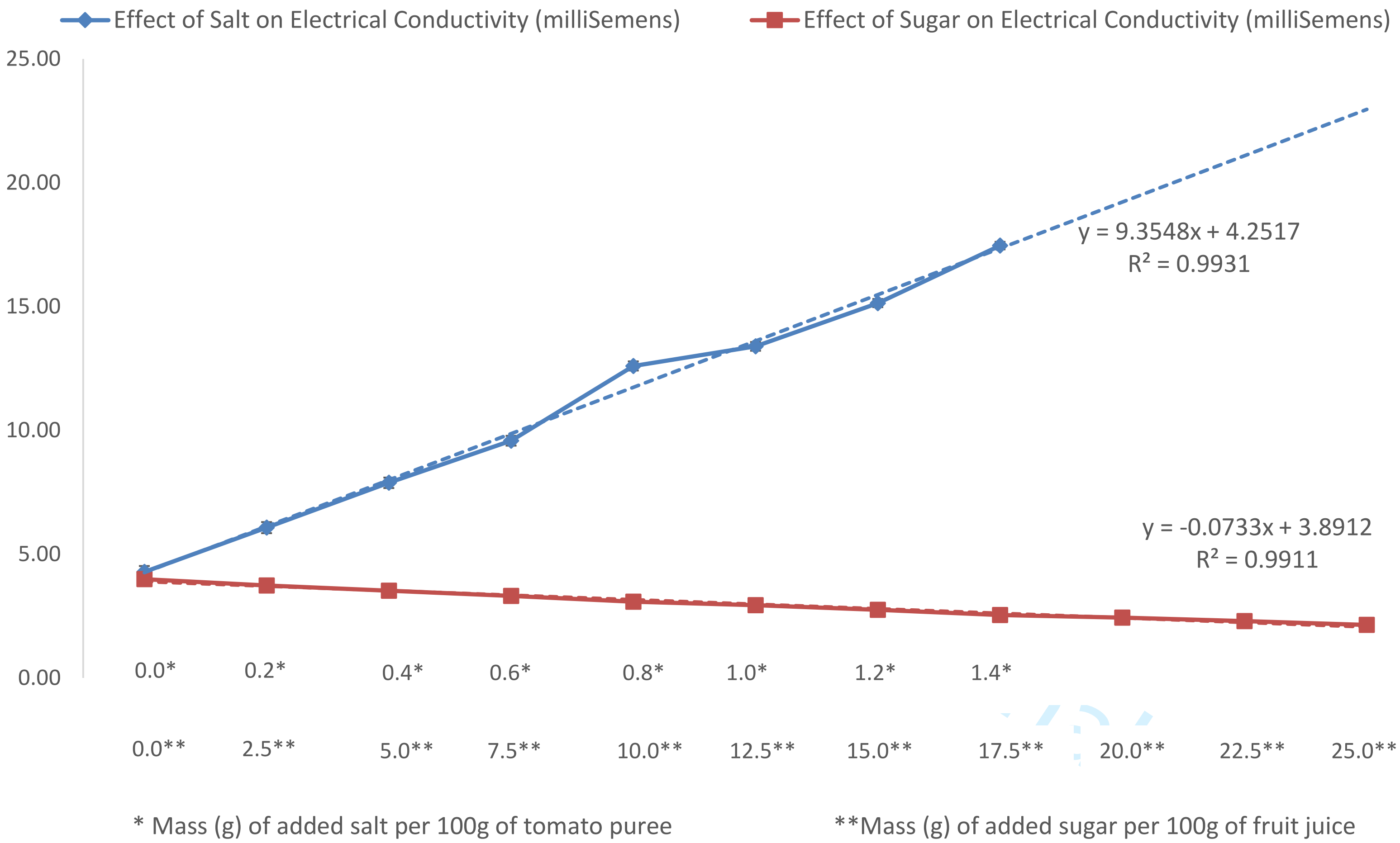

Figure 4: Effect of Salt and Sugar on Electrical Conductivity of Samples

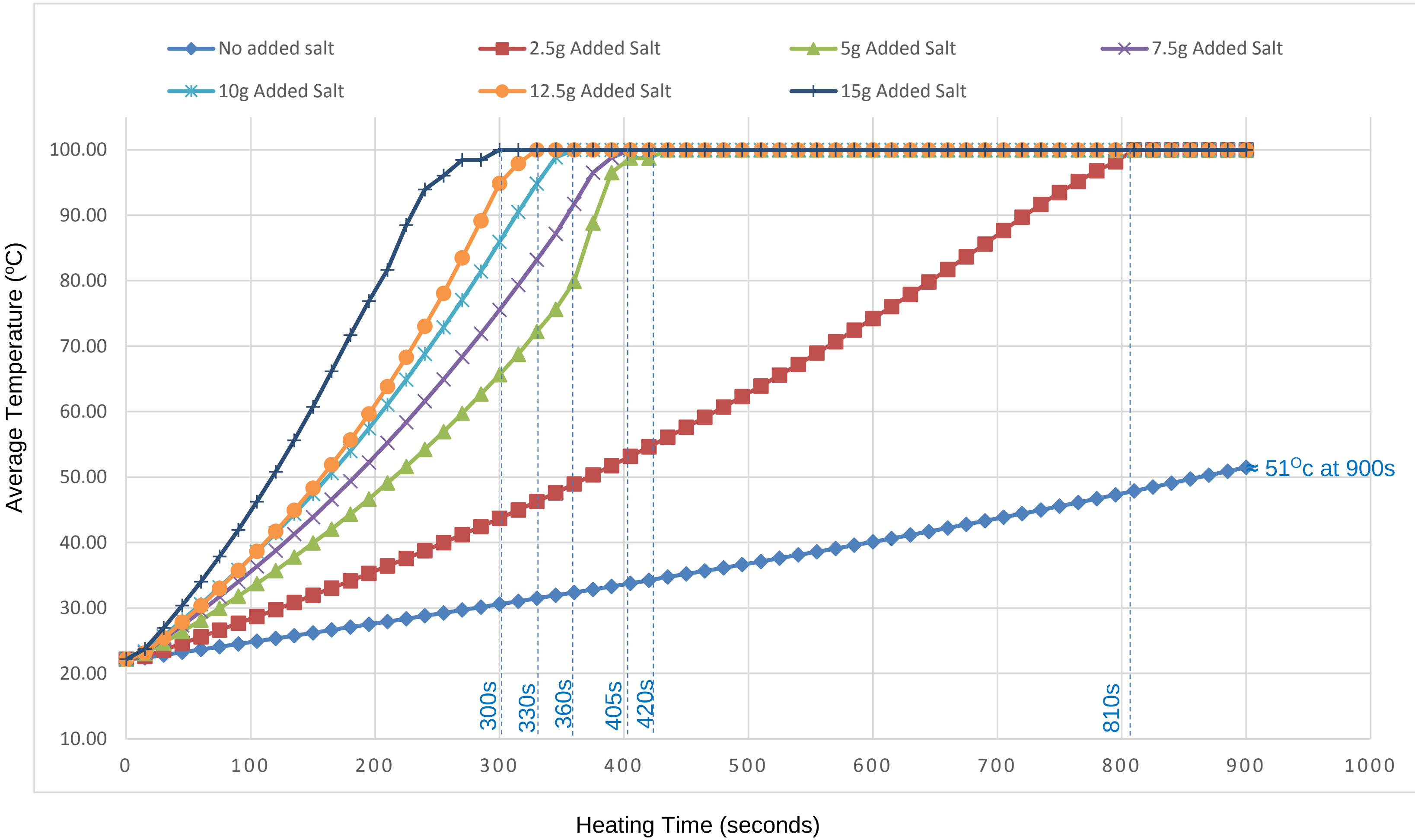

Figure 5: Temperature-Heating Time Curves for 660g Tomato Puree Dehydrated at different salt levels

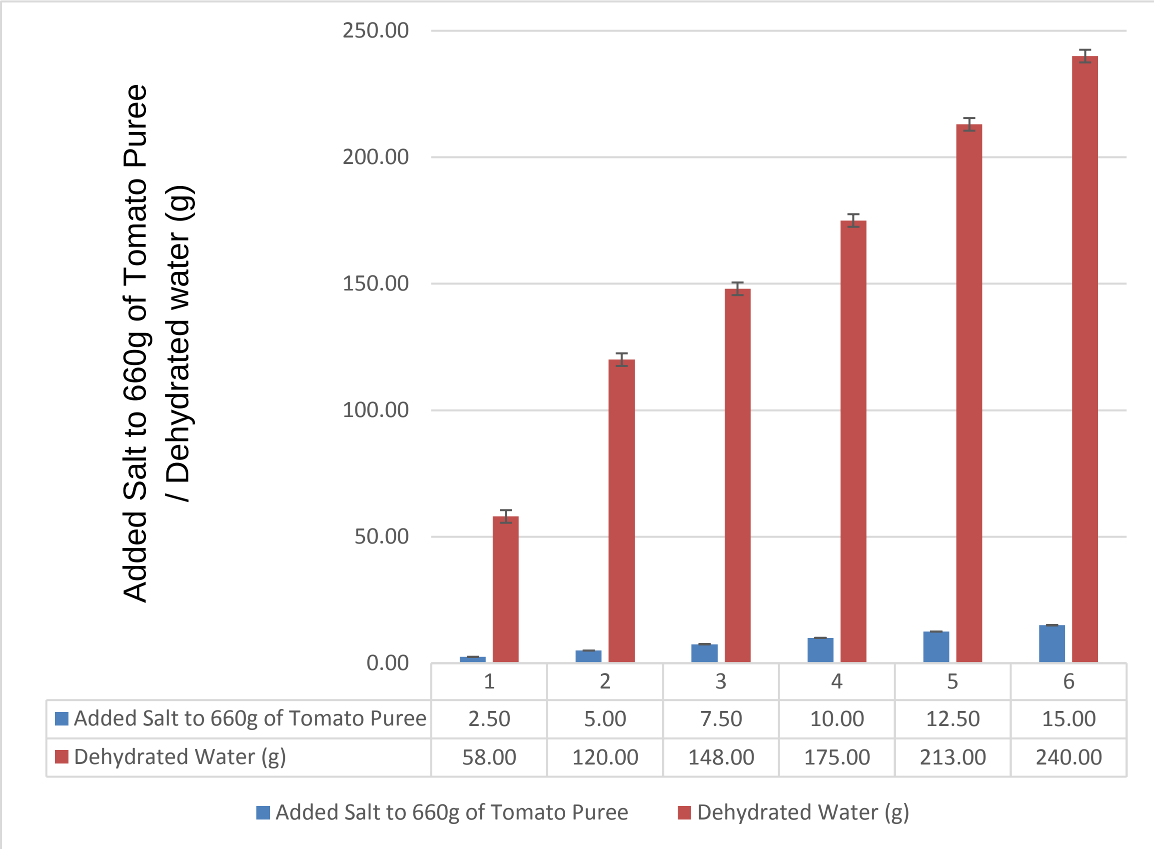

Figure 6: Dehydrated water (g) during ohmic heating processing of 660g tomato puree at different salt levels

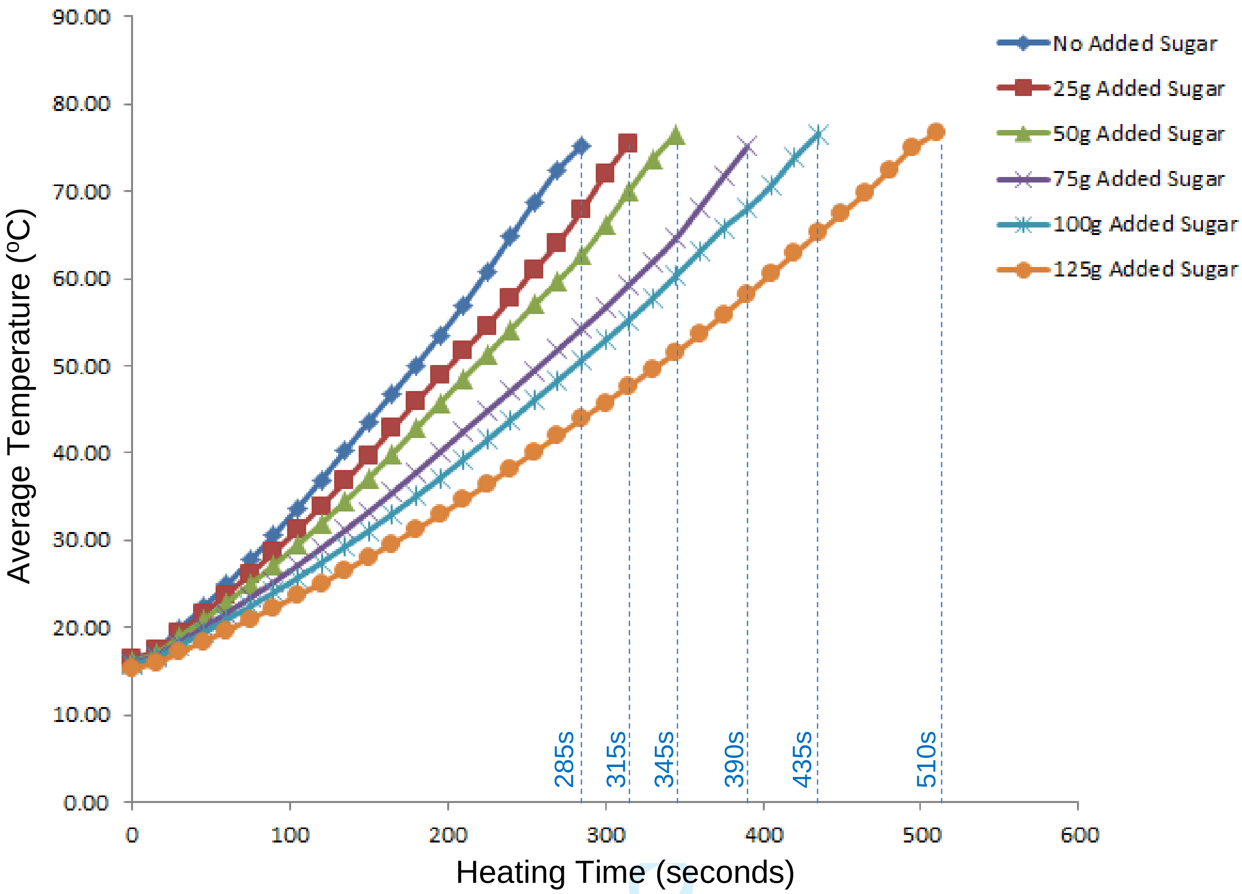

Figure 7: Temperature-ohmic heating time curves for 500g juice pasteurisation at different sugar levels

Table 1: Nutritional Information of Experimental Samples

		Nutritional Information Typical values				
Added Salt* / Sugar (g)**	**Tomato puree (TP) / Fruit Juice (FJ)**	**Energy**	**Fat** Of which: Saturates	**Carbohydrate** Of which: Sugars	**Protein**	**Salt**
0.0*	Per Portion Size (660.0g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	0.1g
	Per 100g	22 kcal 94 kJ	0.5g 0.1g	3.6g 3.6g	1.1g	0.0g
2.5*	Per Portion Size (662.5g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	2.6g
	Per 100g	22 kcal 94 kJ	0.5g 0.1g	3.6g 3.6g	1.1g	0.4g
5.0*	Per Portion Size (665g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	5.1g
	Per 100g	22 kcal 93 kJ	0.5g 0.1g	3.6g 3.6g	1.1g	0.8g
7.5*	Per Portion Size (667.5g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	7.5g
	Per 100g	22 kcal 93 kJ	0.5g 0.1g	3.6g 3.6g	1.1g	1.1g
10.0*	Per Portion Size (670g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	10.0g
	Per 100g	22 kcal 93 kJ	0.5g 0.1g	3.5g 3.5g	1.1g	1.5g
12.5*	Per Portion Size (672.5g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	12.6g
	Per 100g	22 kcal 92 kJ	0.5g 0.1g	3.5g 3.5g	1.1g	1.9g
15.0*	Per Portion Size (660g)	145 kcal 620 kJ	3.3g 0.7g	23.8g 23.8g	7.3g	15.0g
	Per 100g	22 kcal 92 kJ	0.5g 0.1g	3.5g 3.5g	1.1g	2.2g
0.0**	Per Portion Size (500.0g)	238 kcal 995 kJ	<0.1g <0.1g	52.5g 52.5g	2.5g	<0.01g
	Per 100g	48 kcal 199 kJ	<0.1g <0.1g	10.5g 10.5g	0.5g	<0.01g
25.0**	Per Portion Size (525.0g)	337 kcal 1415 kJ	<0.1g <0.1g	78.7g 78.7g	2.5g	<0.01g
	Per 100g	64 kcal 270 kJ	<0.1g <0.1g	15.0g 15.0g	0.5g	<0.01g
50.0**	Per Portion Size (550.0g)	435 kcal 1835 kJ	<0.1g <0.1g	105.0g 105.0g	2.5g	<0.01g
	Per 100g	79 kcal 334 kJ	<0.1g <0.1g	19.1g 19.1g	0.5g	<0.01g
75.0**	Per Portion Size (575.0g)	533 kcal 2255 kJ	<0.1g <0.1g	131.2g 131.2g	2.5g	<0.01g
	Per 100g	93 kcal 392 kJ	<0.1g <0.1g	22.8g 22.8g	0.4g	<0.01g
100.0**	Per Portion Size (600.0g)	632 kcal 2675 kJ	<0.1g <0.1g	157.5g 157.5g	2.5g	<0.01g
	Per 100g	105 kcal 446 kJ	<0.1g <0.1g	26.3g 26.3g	0.4g	<0.01g
125.0**	Per Portion Size (625.0g)	731 kcal 3095 kJ	<0.1g <0.1g	183.8g 183.8g	2.5g	<0.01g
	Per 100g	117 kcal 495 kJ	<0.1g <0.1g	29.4g 29.4g	0.4g	<0.01g

Analysis by NutritionalPro Software, Food Data Services, Beverley, UK

Table 2: Comparative analyses of the temperature developments during Ohmic heating over varying salt* and sugar** levels

Added Salt* / Sugar** (g)	Means				Wikis' Lambda	F	**p-value (Sig.)**	η^2	Pairwise Comparisons					
	TKTP1	TKTP2	TKTP3	TKTP4					p-value (TKTP1&2)	p-value (TKTP1&3)	p-value (TKTP1&4)	p-value (TKTP2&3)	p-value (TKTP2&4)	p-value (TKTP3&4)
0.0*	29.281	29.079	30.472	30.879	.141	(3, 58)	**<.001**	.859	<.001	<.001	<.001	<.001	<.001	<.001
2.5*	58.728	58.079	57.969	57.335	.305	(3, 58)	**<.001**	.695	<.001	<.001	<.001	**=.058**	<.001	<.001
5.0*	76.957	70.782	80.728	81.845	.553	(3, 58)	**<.001**	.447	<.001	<.001	<.001	<.001	<.001	<.001
7.5*	77.857	78.317	80.586	81.281	.579	(3, 58)	**<.001**	.421	**=.408**	=.001	<.001	<.001	<.001	=.007
10.0*	81.947	80.751	82.276	82.090	.516	(3, 58)	**<.001**	.484	<.001	**=.159**	**=1.000**	<.001	<.001	**=1.000**
12.5*	81.444	80.273	79.401	78.726	.345	(3, 58)	**<.001**	.655	<.001	<.001	<.001	**=.166**	<.001	**=.485**
15.0*	87.428	87.035	86.817	85.292	.569	(3, 58)	**<.001**	.431	**=.098**	**=.643**	<.001	**=1.000**	<.001	<.001
0.0**	47.123	45.037	47.157	45.850	.136	(3, 19)	**<.001**	.864	<.001	**=1.000**	<.001	=.001	**=.064**	<.001
25.0**	44.802	43.466	44.472	43.767	.069	(3, 20)	**<.001**	.931	=.002	**=.119**	<.001	**=.074**	**=1.000**	<.001
50.0**	43.355	42.517	42.935	42.741	.131	(3, 21)	**<.001**	.869	=.002	**=.055**	=.013	**=.951**	**=1.000**	**=.193**
75.0**	41.946	40.915	41.840	41.643	.155	(3, 24)	**<.001**	.845	<.001	**=1.000**	**=.384**	=.033	**=.260**	**=.172**
100.0**	42.637	41.862	42.539	42.253	.189	(3, 27)	**<.001**	.811	=.004	**=1.000**	**=.058**	**=.104**	**=1.000**	=.001
125.0**	45.287	43.868	45.072	45.629	.255	(3, 35)	**<.001**	.745	<.001	**=.161**	**=1.000**	=.003	=.007	=.031